

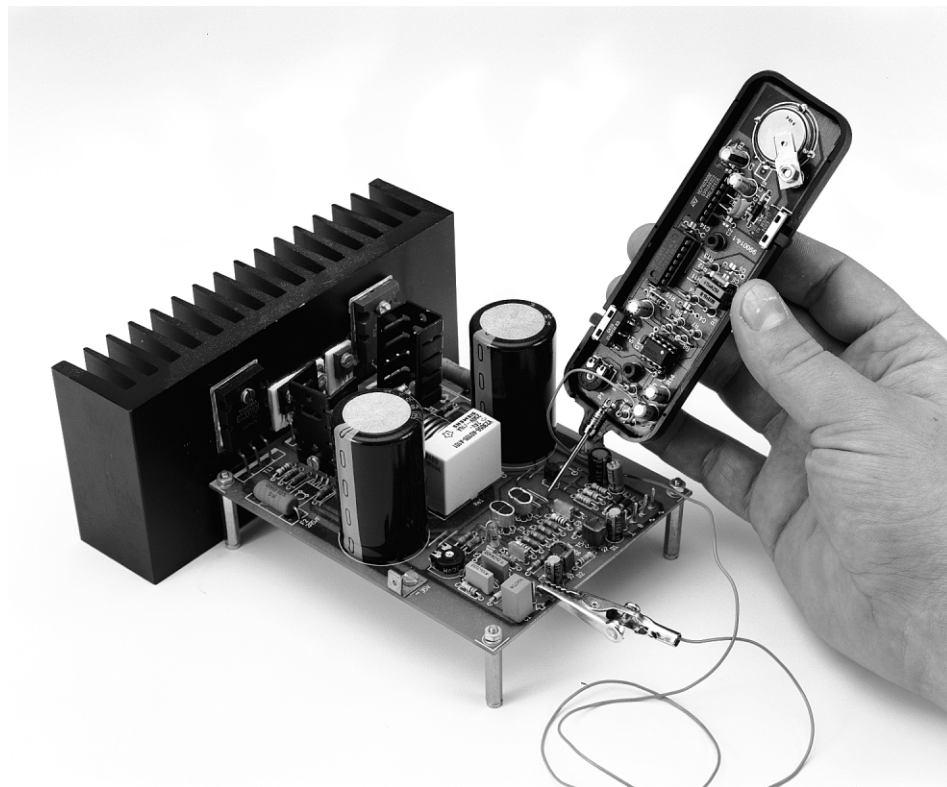
noise generator

white or pink noise at the flick of a switch

Strictly speaking, noise is a composite of a great number of signals at many, varying frequencies. It is a random quantity which generally has no regular or repetitive character.

Although it is usually an unwanted quantity, noise may be used to analyse the performance of an audio system. A noise generator is, therefore, indispensable for much work in an audio workshop.

Unfortunately, many amateur audio enthusiasts find the price of noise generators beyond their means. For them, this article describes an affordable, small noise generator that is easy to build.



Main parameters

Frequency range	20–20000 Hz
Signal output	White noise or pink noise
Signal source	Pseudo random noise generator
Output voltage	2 V _{p-p} max.
Attenuation	About 10 dB
Power supply	lithium battery
Current drain	About 4.5 mA

INTRODUCTION

Noise is either artificial (man-made) or natural. Man-made noise is normally impulsive and stems mainly from electrical machines.

Natural noise is mainly due to cosmic electromagnetic radiation that invades a system through either an intentional or accidental aerial. Also, all

circuit components generate thermal noise. Thermal noise is completely random and occurs over the entire frequency range from d.c. to infinity. For test purposes in audio equipment, only noise in the audio frequency range of 5–20000 Hz is of course of interest.

A distinction must be made between white noise, red noise and

pink noise. White noise has equal energy throughout the frequency range from zero to infinity, but the energy of red and pink noise is inversely proportional to the frequency in a (limited) frequency spectrum. The names white and pink derive from the spectral division of visible colours (white light contains all colours, while red and pink light is filtered)

The power per unit bandwidth of white noise is constant. This means that noise signals of equal amplitude are probable over the entire electromagnetic spectrum. White noise has an energy distribution that is described statistically by the Gaussian distribution curve.

The power density distribution of red and pink noise varies in inverse proportion to frequency: that of red noise at a rate of 6 dB/octave or 20 dB/decade, and that of pink noise at a rate of 3 dB/octave or 10 dB/decade.

one device to another (of the same type!). As this voltage is small, it becomes difficult to design an amplifier whose output is fairly constant with such a wide spread of input voltages. Another is that many semiconductor devices exhibit so-called popcorn noise, which manifests itself, as the name implies, by short, irregularly occurring peaks in the output, which play havoc with the measurement.

It is therefore clear that a home constructed noise generator needs a much more reliable means of producing noise. The present design uses a digital generator, which not only ensures a well-defined output, but has the added advantage of requiring only a (relatively) small supply voltage.

The present design is based on a rectangular waveform generator whose output is applied to a series of shift registers. An XOR gate is used to produce a reset pulse that initiates the

circuitry associated with IC_{3a} forms the (analogue) amplifier and filter section.

The rectangular generator operates at a frequency of 50 kHz. Its output is applied to the clock input of IC₂, which is an 18-stage register. These stages are interconnected in a loop with the output of one linked to the data input of the next. Gates IC_{1c} and IC_{1d} provide the requisite sequence of operation.

Network R₃-C₃ provides a power-on reset. To ensure that the registers in IC₂ start working correctly on power-on, it is essential that pin 8 of IC₁ is then logic low.

The level of the output at pin 1 of IC₂ is very nearly peak-to-peak, which is too high for operational amplifier (op amp) IC_{3a}. This is, therefore, remedied by potential divider R₄-R₅.

Operational amplifier IC_{3a} functions as a voltage follower that provides the requisite low source impedance for the filter between the op amp

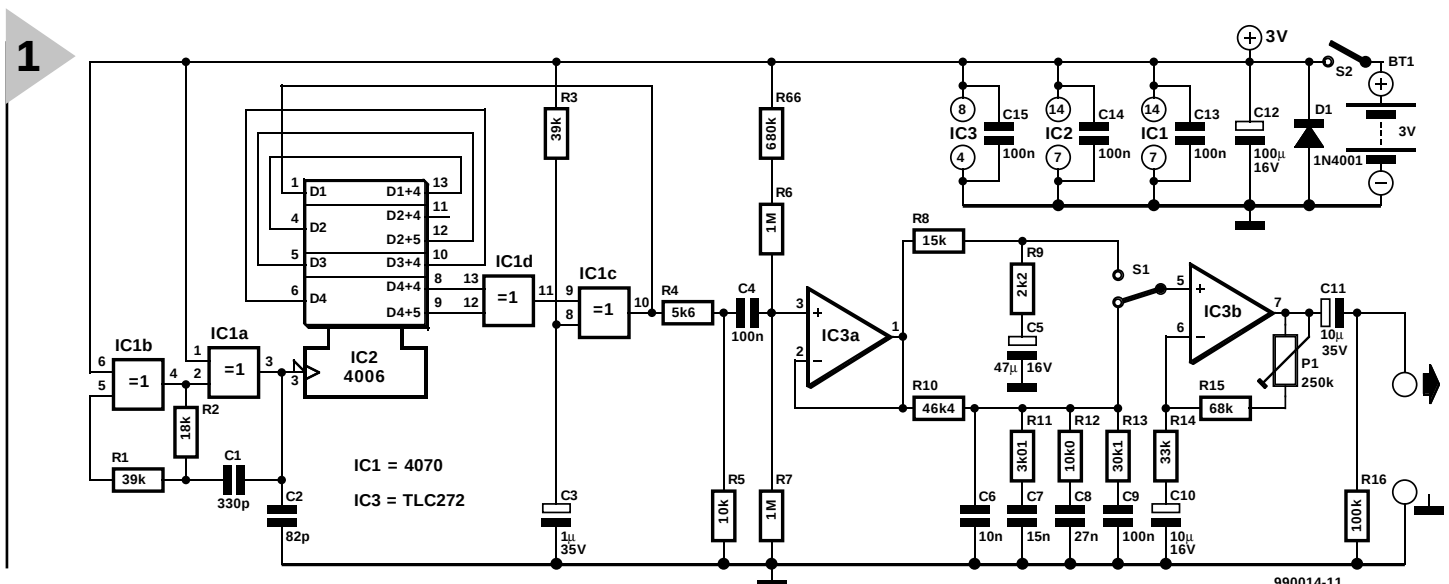


Figure 1. The circuit of the noise generator consists of a digital signal generator section and an analogue amplifier and filter section.

Because of these properties, white noise is particularly useful for measurements with an oscilloscope or spectrum analyser, and pink noise for measurements that involve a one-third-octave analyser.

DESIGN CONSIDERATIONS

Professional noise generators often operate at the knee of the limiting characteristic of zener diodes, which requires a very stable supply voltage. Other means are reverse-biased diodes or the base-emitter junction of bipolar transistors.

A drawback of most of these methods is that the device used as the noise source has to be selected for several reasons. One is that the generated noise voltage varies substantially from

start of a new count sequence. The signal so generated has a statistically distributed frequency and constant output level, and is therefore similar to white noise. The difference between the two is that normal white noise is random in the time domain, whereas the noise produced by the shift register is a pseudo random noise, that is, a noise that repeats itself regularly. For the present design, this presents absolutely no difficulties whatsoever.

CIRCUIT DESCRIPTION

In **Figure 2**, IC_{1a} and IC_{1b} form the rectangular waveform generator, IC₂ contains the shift registers, and the cir-

and switch S₁.

The supply for IC₃ is single and resistors R₆, R₇ and R₆₆ therefore shift the operating point of the op amp slightly below $U_B/2$. This arrangement ensures that the op amp can be driven symmetrically. In spite of the low supply voltage (3 V), the op amp provides an output signal of about 2 V_{p-p}.

The output of IC_{3a} is a pseudo random noise signal. Pink noise is obtained by putting the white noise signal through a filter that has a slope of -3 dB/octave. This roll-off is obtained by a four-section RC filter consisting of resistors R₁₀-R₁₃ and capacitors C₆-C₉. The filter covers a frequency range of ten octaves and, because 1% resistors and 2% capacitors are used, has an error of only 0.5 dB. If the capacitors are not selected appropriately, the error

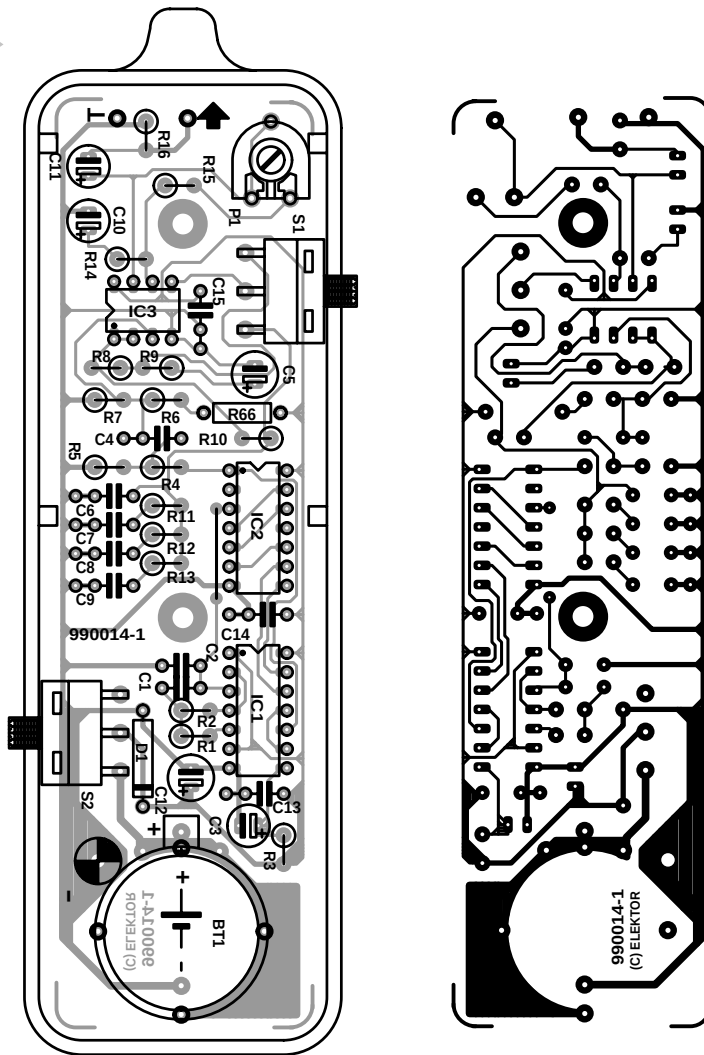


Figure 2. The single-sided printed-circuit board fits exactly in a probe enclosure.

may rise to 2 dB. Whatever, the noise amplitude is suitably attenuated by the filter.

The output of the filter is applied to switch S_1 which enables either white noise or pink noise to be selected. The amplitude of the white noise signal is made equal to that of the pink noise by divider R_8 - R_9 .

The voltage drop across capacitor C_{10} is equal to the direct voltage at the operating point of IC_{3a} .

Op amp IC_b amplifies the signal arriving from the switch to give an output signal at a level of $2 V_{p-p}$ across terminals PC_1 , PC_2 .

Resistor R_{16} ensures that even when the output is open-circuit, the polarizing voltage for C_{11} is maintained.

The generator is powered by a 3 V lithium battery. A polarity protection diode is not used, since this would lower the battery voltage unnecessarily. If readers want protection, diode D_1 may be used as shown. This will short-circuit the battery if it is connected with

wrong polarity and so protect the generator from damage. The generator draws an operating current of about 4.5 mA.

CONSTRUCTION

The generator is best built on the printed circuit board in **Figure 2**, which is available through our Readers Services – see section toward the end of this magazine.

Virtually all components should be mounted vertically. Since the board cannot be screwed down, it is advisable to fit it tightly into the enclosure with the aid of some pieces of foam rubber. The specified enclosure is normally intended for a probe.

The output voltage may be adjusted with a screwdriver through an appropriate aperture in the lid of the enclosure or the spindle of the relevant potentiometer may be made to protrude through the lid.

Do not overlook the wire bridge near IC_2 and do mind the polarity of the electrolytic capacitors, ICs and

Parts list

Resistors:

$R_1, R_3 = 39 \text{ k}\Omega$
 $R_2 = 18 \text{ k}\Omega$
 $R_4 = 5.6 \text{ k}\Omega$
 $R_5 = 10 \text{ k}\Omega$
 $R_6, R_7 = 1 \text{ M}\Omega$
 $R_8 = 15 \text{ k}\Omega$
 $R_9 = 2.2 \text{ k}\Omega$
 $R_{10} = 46.4 \text{ k}\Omega, 1\%$
 $R_{11} = 3.01 \text{ k}\Omega, 1\%$
 $R_{12} = 10.0 \text{ k}\Omega, 1\%$
 $R_{13} = 30.1 \text{ k}\Omega, 1\%$
 $R_{14} = 33 \text{ k}\Omega$
 $R_{15} = 68 \text{ k}\Omega$
 $R_{16} = 100 \text{ k}\Omega$
 $R_{66} = 680 \text{ k}\Omega$
 $P_1 = \text{preset potentiometer, } 250 \text{ k}\Omega$

Capacitors:

$C_1 = 330 \text{ pF}$
 $C_2 = 82 \text{ pF}$
 $C_3 = 1 \mu\text{F}, 35 \text{ V, radial}$
 $C_4, C_9, C_{13}-C_{15} = 0.1 \mu\text{F}$
 $C_5 = 47 \mu\text{F}, 16 \text{ V, radial}$
 $C_6 = 0.01 \mu\text{F}$
 $C_7 = 0.015 \mu\text{F}$
 $C_8 = 0.027 \mu\text{F}$
 $C_{10} = 10 \mu\text{F}, 16 \text{ V, radial}$
 $C_{11} = 10 \mu\text{F}, 35 \text{ V, radial}$
 $C_{12} = 100 \mu\text{F}, 16 \text{ V, radial}$

Semiconductors:

$D_1 = 1\text{N}4001$

Integrated circuits:

$IC_1 = 4070$
 $IC_2 = 4006$
 $IC_3 = \text{TLC}272\text{CP}$

Miscellaneous:

$BT_1 = \text{lithium battery Type CR2032}$
 with holder for board mounting
 $S_1 = \text{right-angled slide switch with 1}$
 change-over contact for board mounting
 $S_2 = \text{right-angled slide switch with 1}$
 on contact for board mounting
 Probe enclosure
 Printed-circuit board, Order no.
 980014-1

diode D_1 if used.

A test prong, which is readily made from a 25–50 mm (1–2 in) length of stout copper wire, must be connected securely to terminal PC_1 ; the earth connection is best made from a short length of stranded, insulated circuit wire soldered to PC_2 .

TESTING THE GENERATOR

The generator cannot really be tested properly without an oscilloscope. Check that the signal at pin 3 of IC_1 has a rectangular waveform and a frequency of 50–55 kHz. When that is so, the signal at pin 1 of IC_2 should be a pseudo random noise signal. This is seen on the scope as two limiting (horizontal) lines separated by a distance equal to the supply voltage. When the time base of the scope is adjusted appropriately, there appear between

these two lines at irregular distances level jumps, visible as faint lines, which represent the actual noise signal.

It is advisable to check the operating point of IC₃, since this may stray from device to device. To this end, remove IC₁ and IC₂ from their socket and apply a sinusoidal voltage at a mid-range frequency and at a level of 1 V_{rms} between pin 1 of IC₁ or IC₂ and earth. This signal should be visible undistorted at pin 1 of IC₃. Increase the level of the sinusoidal signal until the peak of the voltage at pin 1 of IC₃ begins to flatten. This flattening should be absolutely symmetrical at both the positive and the negative peaks. If this is not so, the operating point should be adapted slightly by altering the value of R₆₆ as required. This procedure is essential to ensure maximum undistorted output voltage. In the prototype, the combined value of R₆ + R₆₆ is exactly 1.7 MΩ.

Set S₁ to white noise output and turn P₁ fully clockwise, whereupon the noise signal should be clearly visible on the scope connected to the output of the generator.

OPERATION

The spectra of white noise and pink noise are shown in **Figure 3**. The frequencies contained in the white noise signal are evenly distributed over the audio range up to about 20 kHz. The response dips a few dB towards 30 kHz, but the actual level of the spectrum is, of course, not important.

In practical operation, the output signal of the generator can be applied to any accessible point in the equipment on test by simply touching it with the test prong. Take care, however, not to overload the equipment on test. Note that noise signals contain very high peaks that may damage tweeters. A white noise signal enables, for instance, testing the operation of a volume control or a sound level control.

Pink noise may be used to check room acoustics or the effect furniture or curtains have on the performance of loudspeakers. This enables the loudspeaker to be trimmed to the room requirements.

In any case, it is advisable to carry out a number of experiments with the noise generator before using it in practical testing.

[980014]



Figure 3. Spectra of white noise and pink noise.

